The S/X-Band Microwave Feed System for NASA's First Bcamwaveguide Antenna

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ABSTRACT

The configuration, detail design, and performance of the dual S/X-band microwave feed system for the first Deep Space Network (DSN) beamwaveguide (BWG) antenna&reported in this paper. By using existing spare components, simplifying the design of new compncnts, and using new fabrication techniques and material, this feed system was implemented successfully with a small budget and a very tight schedule. The measured noise temperature of the feed systems is 17.5 Kelvin for S-band and 24.0 Kelvin for X-band, which agrees very closely with the predicted performance.

INTRODUCTION

Deep Space Station 13 (1)SS 13), located at the Deep Space Communication Complex in Goldstone, CA, is NASA's first BWG tracking antenna. This antenna, which is primarily used for research and development tasks, is an elevation-over-azimuth type using wheel and track azimuth bearings [1]. DSS 13 has a parabolic main reflector which is 34 m in diameter and a hyperbolic subreflector which is 3.43 m in diameter. The subreflector is supported by a low-optical cross-section tripod. The main reflector and the subreflector arc both shaped to provide near uniform aperture illumination [2]. The reflector surfaces are designed and fabricated for providing high performance at 32 Ghz.

'1-he BWG feed systcrn consists of a beam magnifier ellipse located in a pedestal room below ground level that transforms a 22-dB gain feedhorn into a high-gain 29-dB gain pattern for input to a standard four-mirror (two flat and two paraboloid) BWG system (see Figure 1), The design of the upper section of the B WG is based on a Geometrical Optics (G.O.) criteria which guarantees a perfect image from a reflector pair. The system was initially designed for operation at 8.45 GHz (X-band) and 32 GHz (Ka-band) and has less than 0.2-dB loss (determined by comparing the gain of a 29-dB gain horn feeding the dual-shaped reflector system with that obtained using the BWG system).

In BWG antennas, the microwave front-end equipment is placed in the pedestal room. There are several advantages in having the microwave feed equipment in the basement: the microwave equipment will be stationary at all times, ease of installation and maintenance, and the capability of using several feed systems without introducing additional loss due to the blockage. At DSS 13, several different microwave feed systems are placed about the rotating ellipsoid. Each microwave feed can then be selected remotely by aligning the ellipsoid in the direction of that feed.

This report describes the S/X-band feed system implemented for DSS 13. Section I covers the general theory of the operation of the feed system, Section II describes the detail design, and Section III shows the performance

S/X-BAND FEED THEORY OF OPERATION

The DSS 13 S/X-band microwave feed system is capable of receiving S- and X-band signals simultaneousl y. Figure 2 shows the main components of this feed system: the X-band feed, the S-band feed, the S/X-band dichroic reflector, and the X-band flat reflector. The S-band receive frequency band is 2200 to 2300 MHz, and the X-band receive frequency band is 8200 to 8600 MHz.

The S-band signal received from the deep space is collected by the main/sub reflector and is focused at F1 (see Figure 1). Reflectors Ml through M4 guide the signal to the rotating ellipsoid focus F2. The signal is then scattered off the ellipsoid mirror, is reflected by the dichroic reflector, and is focused at the other focal point of the elliptical mirror. This signal is received by the S-band feedhorn in the S-band feed package.

The X-band signal is guided by the beamwaveguide to the basement in the same manner as the S-band signal. However, after scattering off the ellipsoid, it passes through the dichroic mirror with very little loss, reflected by the X-band flat reflector, and is focused at the other focal point of the ellipsoid. This signal is received by the X-band feedhorn in the X-band package.

DETAIL FEED DESIGN

A block diagram of the S/X-band feed packages is shown in Figure 3, The Low Noise Amplifier (LNA) used in this feed system is obtained from a decommissioned 26-m antenna. This is a dual-frequency LNA (i.e., it contains an X-band LNA and an S-band LNA in one cryogenic package). The S-band and the X-band feeds are packaged separately; however, they are physically connected since they share the same LNA package. The feedhorns are wideband

corrugated feedhorns. The gain of the feedhorns is 19.1 dB for S-band and 25.0 dB for X-band, The polarizers provide the capability to select Right-hand Circular Polarization (RCP) or Left-hand Circular Polarization (LCP) reception. In the S-band package, the position of the polarizer can be changed easily by the use of the rotary joints; but in the X-band package, the position of the polarizer is fixed. To change polarization on the X-band, the polarizer has to be unscrewed and then rotated; however, spacers have been supplied to allow addition of rotary joints at a future date. The couplers are used for injection of noise to check the linearity of the LNAs. The waveguide switches are used to connect the LNAs to the feedhorns or to the ambient loads for noise temperature and linearity measurements.

The S/X-band dichroic reflector is a frequency selective surface that passes the X-band signal but reflects the S-band signal. The S/X-band dichroic plate used at DSS 13 is a 198.1-cm X 141.5-cm X 3.576-cm rectangular aluminum plate with an elliptical perforated area (see Figure 4). The holes in the perforated area are based on an old dichroic plate design [3]. This design employs the Pyleguide holes originally used by Pyle [4]. However, to reduce the fabrication cost, the corner radius of the holes was increased from 0.013 cm to 0.318 cm as shown in Figure 4. An analysis of the propagation constant of the fields in the Pyleguide holes shows that the change in the propagation constant due to this modification is far less than the change due to the tolerances of the other critical dimensions of the holes [5]. This minor change reduced the fabrication cost of the S/X dichroic reflector by more than 60%.

The frames for the S- and the X-band packages were fabricated using extruded aluminum struts. These struts are prefabricated, strong, lightweight, and flexible. Their anodized aluminum surface finish is scratch and corrosion resistant. Since all the elements of the frames are bolted together, it is very easy to modify these frames as needed in the future.

Figure 5 shows the S- and the X-band microwave feed assemblies and their overall dimensions.

FEED SYSTEM PERFORMANCE

The preliminary predicted and measured noise temperatures of the S/X-Band LNAs, microwave feeds, and the overall DSS 13 beamwaveguide antenna are shown on Table 1. The higher noise temperature measured for the X-band LNA is due to the age of that package and cannot be improved casily. The predicts are calculated from the theoretical or measured loss of the individual component of each system. The measurement data for the feeds were made at Goldstone before installation in the antenna pedestal room. The measurements for the overall antenna were made after the feed packages were installed and aligned in the pedestal room.

CONCLUSION

The DSS 13 feed system was implemented successfully with a small budget and a very tight schedule. This was accomplished by using existing spare components, reducing fabrication cost of the new components by simplifying their design, and using new fabrication techniques and material. The measured and predicted performance of the feed systems and the overall antenna agree very closely.

ACKNOWLEDGMENT

REFERENCES

[1]   M. Britcliffe, ct al., *DSS-13 Beam-Waveguide Antenna Project: Phase 1 Final Report*, JPL Document D-8541 (internal document), Jet Propulsion Laboratory, Pasadena, CA, May 15, 1991.

[2]   D.A. Bathker, W. Veruttipong, and P.W. Cramer, "Beam-Waveguide Antenna Performance Predictions with Comparison to Experimental Results," *IEEE Trans. Microwave Theory and Tech., vol. 40, no. 6,* June 1992.

[3]   P.D. Potter, *Improved Dichroic Reflector Design for the 64-Meter Antenna S- and X- Band Feed Systems, JPL Technical Report 32-1526, vol. XIX,* Jet Propulsion Laboratory, Pasadena, California, pp. 55-62, February 15, 1974.

[4]   Pyle, J. R., "Cutoff Wavelength of Waveguides with Unusual Cross Sections," *IEEE Transactions on Microwave, vol. MIT-12, no. 5,* pp. 556-557, Sept. 1964.

[5]   J. C. Chen, 1'.11. Stanton, "Effect of Corner Radius on the Performance of an S/X-band Dichroic Plate with Pyleguide Aperture," JPL Interoffice Memorandum 3327-92-078, Jet Propulsion Laboratory, Pasadena, CA, Nov. 24, 1992,

Table 1. Noise Temperature Predicts and Measurements (Kelvin)

System	S-Band Predicts	S-Band Measurement	X-Band Predicts	X-Band Measurement
LNA	8.3	8.72	12.0	14.09
Feed	17.69	17.5	23.07	25.5
Antenna	37.26	38.0	32.90	35.5
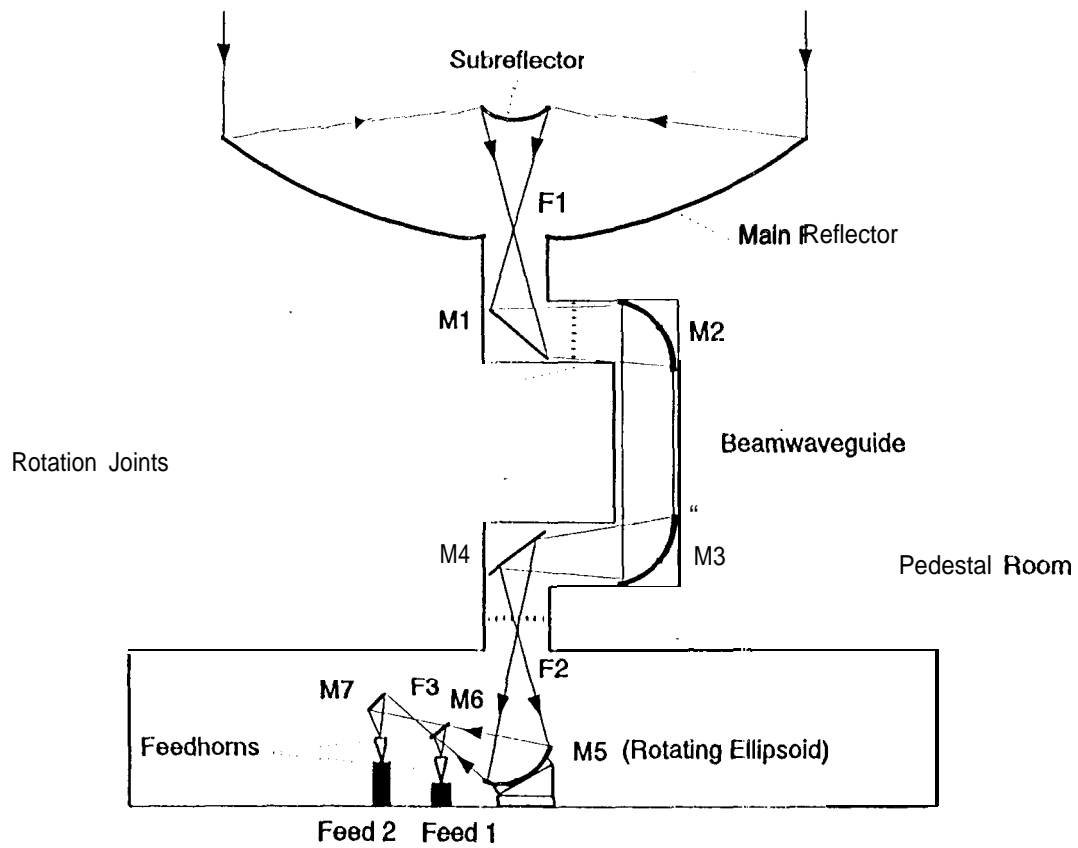
Figure 1. DSS 13 Beamwaveguide Antenna Configuration
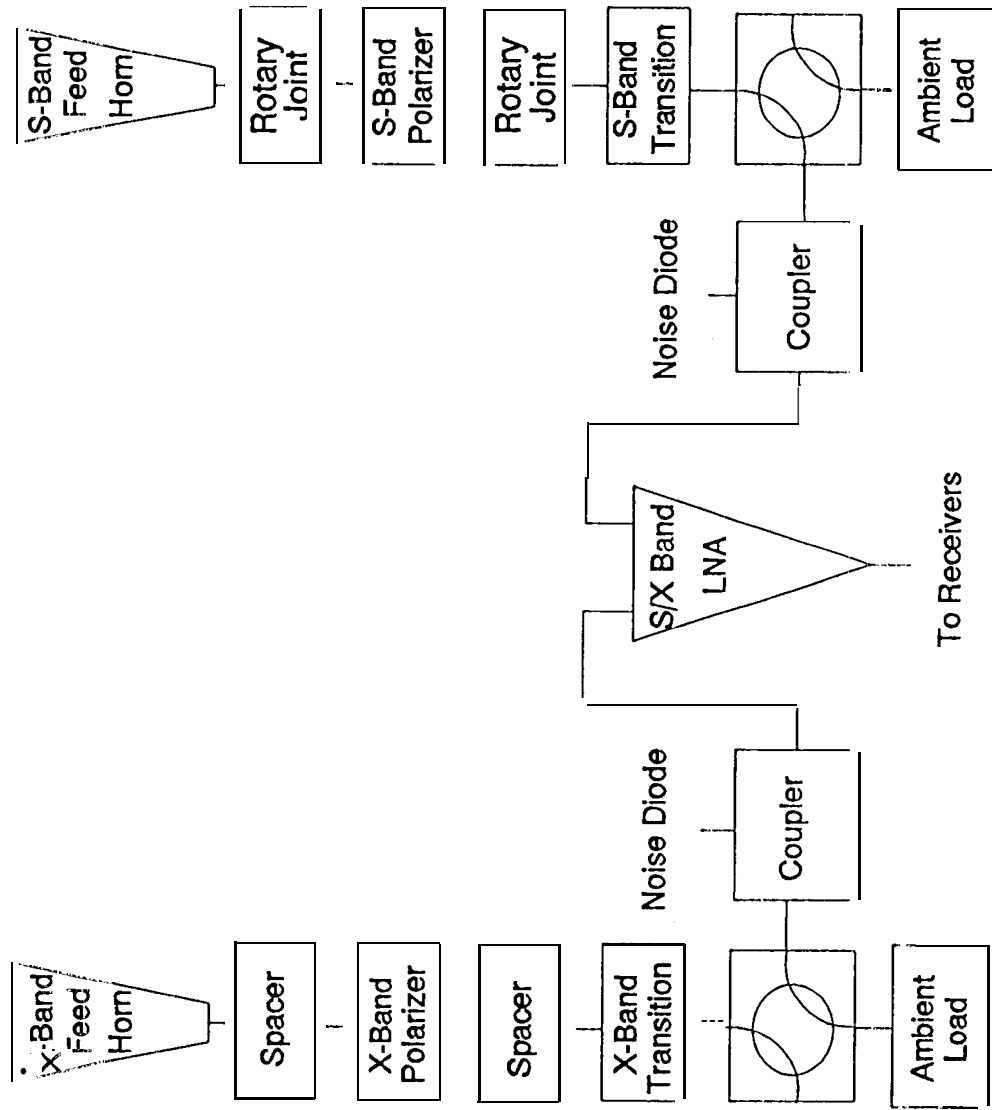
5
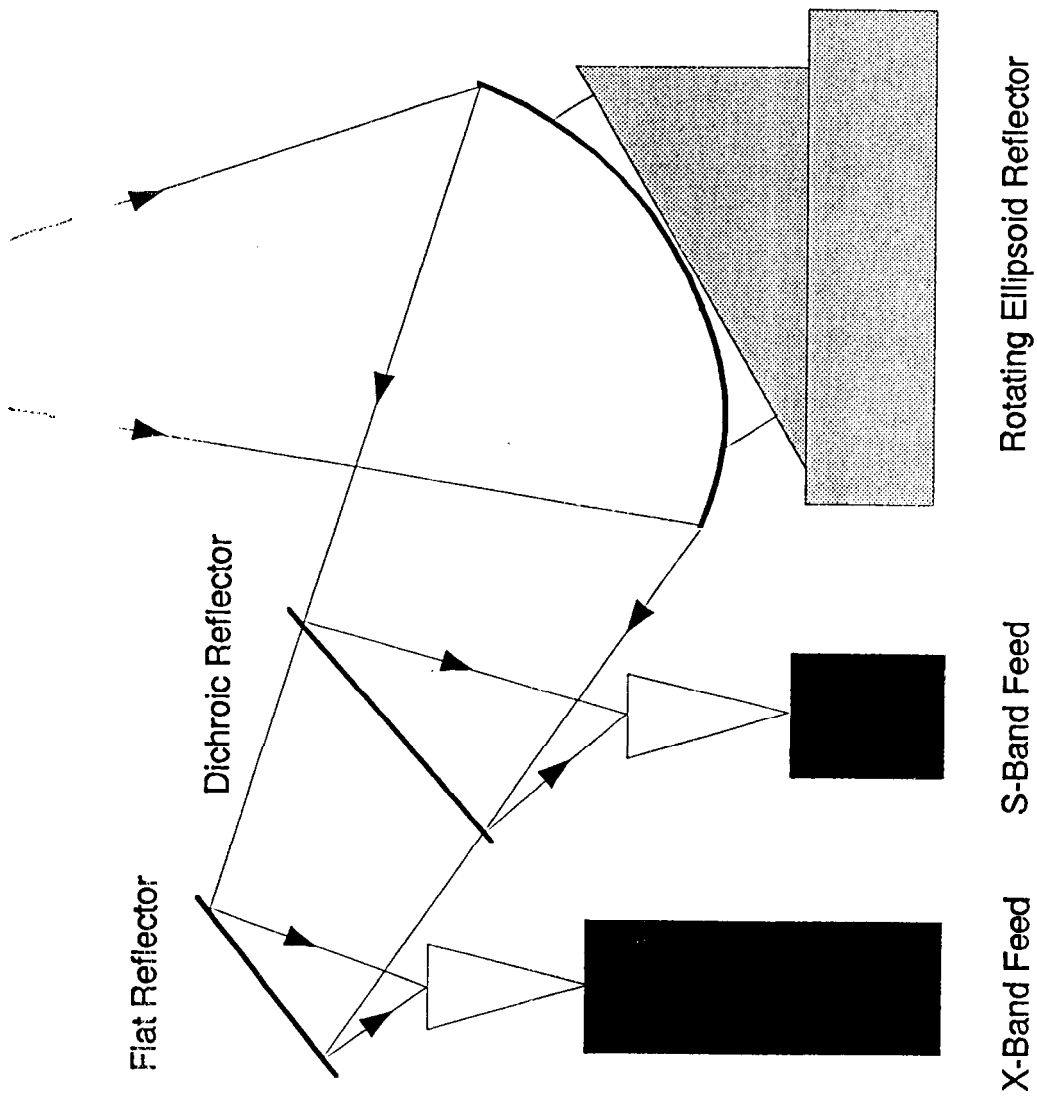
Figure 2. DSS 3 S/X-Band Microwave Feed System

Figure 3. DSS 13 S/X-Band Microwave Feed Block Diagram

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Perforated Area

Solid Area

0.318 cm MAX R

2.199 ± 0.005 cm

0.622 cm Approx.

Ø 2.286 ± 0.005 cm

Modified Pyleguide Design

0.013 cm MAX R

2.199 ± 0.005 cm

0.622 cm

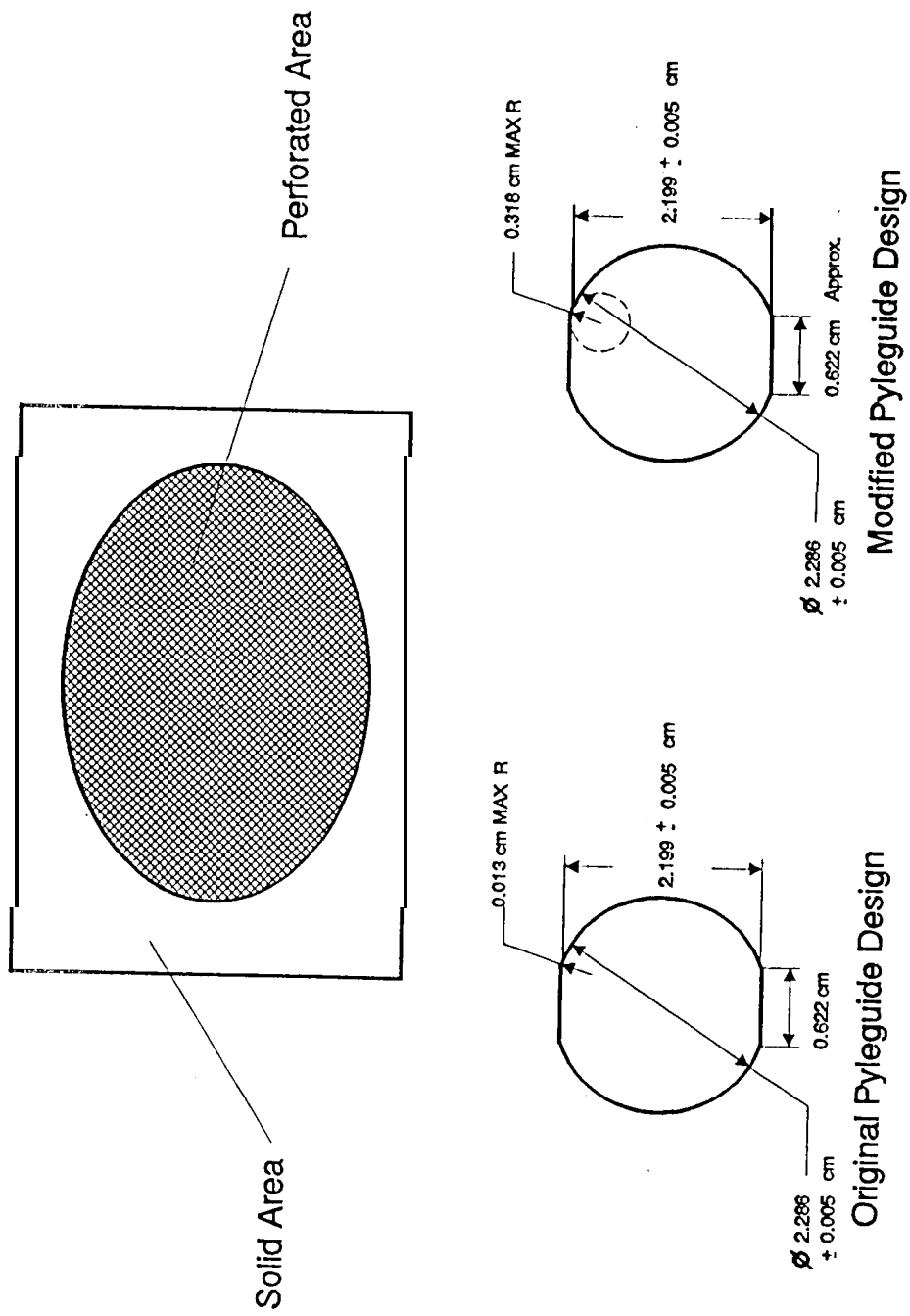Ø 2.286 ± 0.005 cm

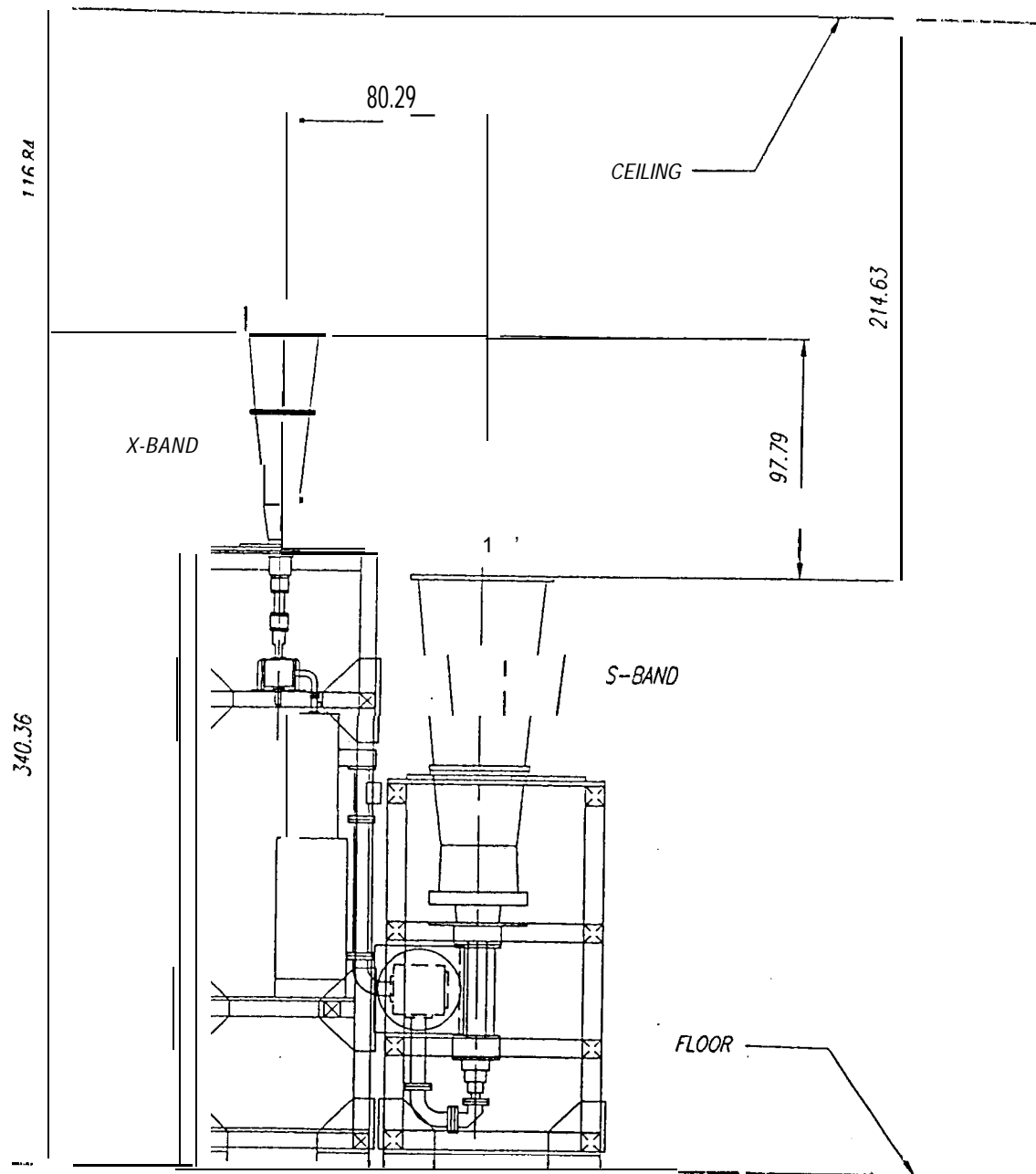**Original Pyleguide Design**

Figure 4. DSS 13 S/X-Band Dichroic Reflector

Figure 5. S- and X-Band Microwave Feed Assemblies